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BIM as an alternative architectural teaching device

Jean-Pierre Basson, *Nelson Mandela University*
Chris Allen, *Nelson Mandela University*

Abstract

Are traditional architectural studio-based teaching methods and tools still applicable, or are they causing a communication barrier between a student and a lecturer? In architectural design studios, promptly submitting projects is a problem. The paper is based on a study conducted by the author between 2016 to 2018 and aims to determine whether information technology (IT), such as building information modelling (BIM), opposed to the conventional method (CM), can improve informed design communication during conceptual design critique sessions. Therefore, contribute to prompt studio-based design project submissions. The research's objectives include understanding BIM as a design tool compared to a visualisation tool to facilitate early design decision-making. Also, to understand how BIM can improve conceptual design information. A rubric was used to evaluate critique sessions based on qualitative attributes of design intention, function, aesthetics, and sustainability. Quantitative and qualitative data were collected from a comparison study between two postgraduate cohorts. One cohort used the CM in the design studio, while the second cohort used the BIM method in the design studio. A framework was created using a literature study to establish the BIM method's capability to improve communication. After completing the cohort comparison study, four themes become apparent: competencies, relationship, time and non-participation. Findings include improved drawings, availability of different drawing types, accuracy and reduced time spent on redundant work and reduced costs. Based on the findings, it can be concluded that BIM can improve design communication between a student and a lecturer during the conceptual design stage, leading to prompt submissions. It is recommended that the current teaching pedagogy in the design studio be revisited to incorporate BIM as a design tool as early as the undergraduate programme.

Keywords: Architecture, BIM, communication, conventional method, conceptual design, design studio, education

Introduction

> *My students don't 'connect' to me, so I must be doing something wrong. In addition, my students aren't submitting their projects on time, which influences my pass rate. I don't understand why this is happening, as the project briefs and instructions are similar every year.*

These comments reflect the concerns of a colleague who has been teaching the same design module in architecture for the past few decades. The question to be asked might not be "what did I do wrong?" but rather "are my teaching methods and tools still relevant and applicable in the ever-changing technological global teaching environment?" In other words, are traditional teaching methods and tools still applicable to the current student, and can they relate to these, or are these approaches causing a communication barrier between the student and the lecturer?

The architectural studio is designed around the creative nature of engaging with design projects, real or hypothetical. Why are students struggling to submit studio-based design projects on time using traditional tools and teaching methods? The literature established that the blame is so easily placed on poor time management to explain the lack of submitting completed studio-based projects on time (Shen, Shen & Sun, 2012). The problem, however, appears to have a deeper explanation, which can be traced to communication between the lecturer and the students during the design's different stages, as described by Basson and Allen (2018). Due to the dialogic nature of the design studio, communication plays a vital role in studio-based education. According to Saghafi, Nozffar, Moosavi, and Fathu (2015), the method currently used in architectural studio-based design education is the conventional method (CM) which uses two-dimensional techniques.

The core concern relates to the lack of communication between the student and the lecturer during conceptual design critique sessions. The lack of available information produced by the CM is believed to hinder students from submitting design projects promptly.

However, the question is: What alternative method is available to improve communication? Building information modelling (BIM) is a new approach that is an interactive and information-rich intervention in contrast to the CM (Eastman, Teicholz, Sacks & Liston, 2012; Joannides, Olbina & Issa, 2012). Using IT as a design tool in architectural education, instead of its current use only as a production and visualisation tool, can lead to a more efficient design process. BIM in Architectural, Engineering and Construction (AEC) practice is well-known and established globally. However, the influence and application during the conceptual design phase in architectural education have not been fully explored. Furthermore, using IT in the design process is one of the most controversial issues in architectural education, but very little scholarly research has been done. It raises questions such as "how is the use of the computer going to influence our creativity or problem-solving abilities?" or "are architects embracing the full potential of IT design tools?" as noted by Bertol (1997).

This paper reports on a study exploring using the BIM method as an alternative tool within the design studio to improve how students and lecturers communicate during critique sessions and its direct influence on student submission rates. This paper argues that for architecture students to communicate well-informed design knowledge requires a rethink of the current traditional CM of design studios by implementing the BIM method that promotes efficient design transformation and will improve student submissions.

Literature review

Architectural education was shaped by combining the Beaux-Arts approach established around the studio (also known as the atelier) and the Bauhaus approach that showed the idea of the set curriculum. However, the model most frequently used in contemporary architecture schools is based on the traditional model. The design is regarded as a process instead of a product in the design studio (Salama, 2005). Green and Bonollo (2003) further underscored the statement by Salama by defining the design studio as the heart of architectural design education. The studio is where students visualise and conceptualise their projects and visually represent the proposal to the problem. Furthermore, the studio teaches students to engage critically with architectural knowledge (Green & Bonollo, 2003; Boyer & Mitgang, 1996).

Due to the dialogic nature of the design studio, **communication** is the critical factor to the success of studio-based learning in architectural education. Schön (1984) stated that the pedagogical value of the studio is centred on communication and conversation between the student and the lecturer. Unlike many other learning pedagogies, this allows for a more significant learning experience. The success of a project depends on effective communication. Ineffective communication is thus detrimental to the AEC industry. Therefore, integrating communication skills within the education system offered to architects plays a crucial role in sustaining the future of the architectural profession.

With the development of the personal computer, traditional pen and paper drafting procedures were replaced with computer-aided drafting. The CM can be described as traditional design methods where architectural students use 2D drawings to represent their projects—using manual creation (drafting), updating, processing, and analytics. All relevant professionals must re-enter data manually, which is time-consuming, error-prone, painstakingly slow, and leads to misinterpretation (Sanguinetti, 2015). The designer uses individual lines to represent building components, such as windows, doors, and walls, with no detailed building information, such as what type of glass is used or thermal properties of a specific material.

In studies conducted by Green and Bonollo (2003), Sachs (1999), Salama (2005) and Ostwald (2008), the CM holds limitations when used in the design studio and can be summarised as follows:

- Students' progression to the next year is based on their drawing skill;
- The decision-making process is complicated for students to master, as it requires expertise not yet learned;
- Moving from an initial concept diagram to design development is an area within the studio-based education where students become stuck and fall behind;
- Repetition forms a significant limitation of the design studio where students must redraw the same action without resolving the real issues or without time to be able to solve the real problems; and
- The design studio is expensive due to the resources required in paper and model-building materials to complete projects.

There is a paradigm shift within the AEC industries due to the rapid pace of changing technologies working towards integrated IT projects (Joannides, et al., 2012; Gu & Vries, 2007; Takim, Harris & Nawawi, 2013). **BIM** plays a significant role in leading this transformation to enhance communication and sharing of information (Ahn, Cho & Lee, 2013). Using BIM allows the exchange of data using an information-rich digital or virtual model, of the design project.

When introducing BIM into the curriculum, graduates with BIM training and expertise are more employable than students without or with little BIM expertise. Secondly, BIM holds the possibility of bridging the traditional silos of teaching in AEC education (Rooney, 2013). As stated, BIM has advantages to the education programme, but three challenges were identified that hinder BIM education implementation into architectural education. The first is the lack of BIM expertise, followed by the resistance from academics, and lastly, the existing curriculum holds little or no space for introducing new content (Eastman, et al., 2012; Ahn, et al., 2013; Kim, 2012).

As the AEC industries move towards integrating more BIM technologies into their fields, there is a need for both fully trained graduates and those who will work closely with these BIM technologies and processes. The processes include three, four, and five dimensions instead of two dimensions (Kim, 2012). BIM is mainly used for construction drawing purposes and is not fully exploited in the design phase. This paper focuses on the design phase instead of the documentation phase regarding the use of BIM as a design tool in establishing the relationship between student-lecturer and design communication.

Methodology

The larger research projects sit within the mix-method paradigm. The study used a student questionnaire as a quantitative data collection tool to collect data about a student perception around the traditional design studio and BIM. This paper will focus on the qualitative data collected from an observational study in the form of a cohort comparison study. Figure 1 explains the logical process followed in conducting the research.

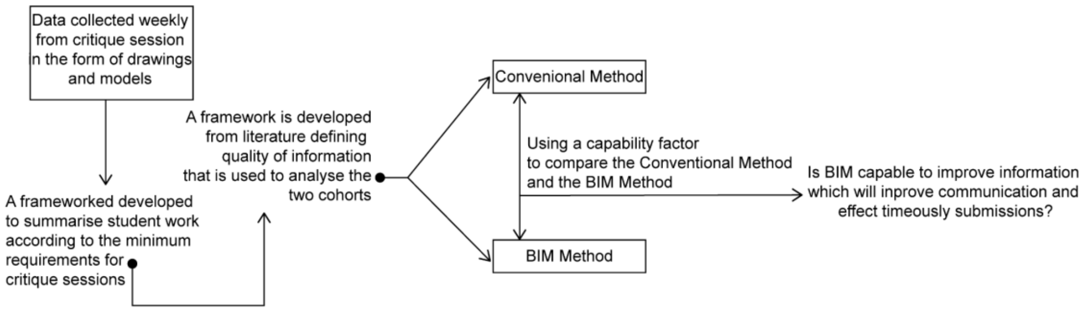

Figure 13: Logical process is taken to conduct the research

The participants in the research were the 2016 and 2014 first-year postgraduate Master of Architecture students. The entire class received the training, but nine students of each year were observed, which represents a third of the class. The data collected for observation was in the form of drawings and models using scans, digital copies or photographs of physical models at each critique session. The 2016 cohort used only the CM in the design studio, whereas the 2017 cohort used the BIM method in the design studio to complete design projects. During the 2016 cohort, the concept of BIM was taught in the Architectural Computer Usage module towards the end of the second semester with no integration into the design studio. In the following year (2017), the content was moved to the early part of the first semester, and students were required to implement their BIM knowledge in the studio-based design project. Thus, the same design project was used during both cohort years.

> *A framework was created which formed the basis for establishing the kind of drawings and information students supplied during each critique session. The framework was established by referencing the competencies of an architectural student as outlined by the government body, the South African Council for the Architectural Profession (SACAP), the client/architect agreement produced by the South African Institute of Architects as well as the design module outcomes as seen in Table 1 (Mashabane, 2012; SAIA, 1999).*

Table 2: Framework for weekly critique session observation modified from the competencies of architectural students and the client/architect agreement compiled during the research study

Evaluation framework			
Design	**Function**	**Appearance**	**Sustainability**
Layout relationships diagrams Use of massing	Construction type Accommodation schedule Site plan	Floor plan(s) Section(s) Elevation(s)	Physical Models Digital illustrative material Calculations Simulations

Descriptive analysis, using deductive coding, was used to analyse the data obtained from the critique evaluation framework. The research was focused on the quality of information that students present to communicate, and therefore, a literature study established six attributes that define quality in communication using only drawings. Table 2 outlines the six attributes defining quality.

Table 3: Defining quality in architectural design by establishing attributes from a literature study

Responsiveness	Establish requirements for the project using critically engaging with all the issues about the building type, accommodation and site issues. Responsiveness furthermore relates to the massing response to the information gathered during the information development stage (Bednar, 2016; Smart, 1995).
Relationship	The ability to associate, link and connect not only different building components and spatial planning (1) but to connect the design in different design platforms (2) and communicate building placement relationship, orientation and site relationships (Bednar, 2016; Eastman, 2012, Smart, 1995).
Modification	To what extent the design can be modified with ease or difficulty to explore design possibilities (Doumbouya, 2016; Shourangiz, 2011; Azhar, 2007).
Accuracy	The exactness or closeness of representing the building design information (Bednar, 2016; Eastman, 2012; Smart, 1995).
Intelligence	The ability of an object to know and identify the real-world building the component is representing (Doumbouya, 2016; Shourangiz, 2011; Azhar, 2007).
Representation	The ability to define and communicate the design process (Doumbouya, 2016; Shourangiz, 2011; Azhar, 2007).

To establish whether the BIM method can enhance informed design communication compared to the CM, a capability factor was used to compare the two cohorts. The capability factor scoring ranged from 1 (no capability) to 4 (completely capable).

Results and findings

The findings are discussed according to the six attributes described in Table 2. The attribute **Responsiveness** established four themes after assessing the work from both cohorts. The first theme of the relationship includes the lack of engaging critically with the project parameters and setting the issues of the design project. The second theme talks about establishing the accommodation schedule, followed by spatial relationships, and selecting the material or construction methods for design communication as seen in Figure 2. The results of the framework used to establish a capability factor for the attribute responsiveness are summarised in Table 3.

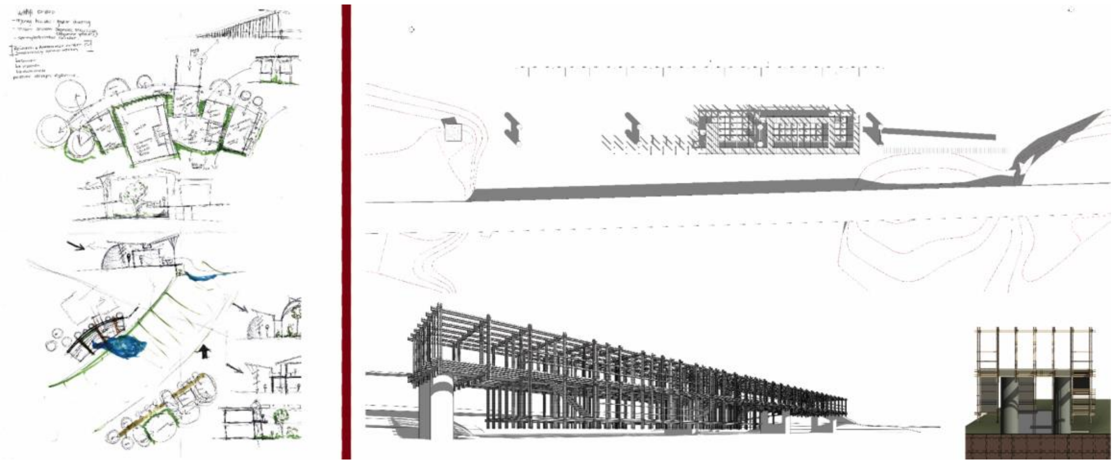

Figure 14: Responsiveness indicating setting up project parameters and deciding on construction techniques and material (CM left, BIM right)

Table 4. Results pertaining to the attribute responsiveness

Capability matrix for responsiveness	**CM**		**BIM**	
Requirement criteria to meet the attribute	Yes	No	Yes	No
Accommodation schedule: Establishing both qualitative and quantitative information.		X	X	
Use of 3D conceptual massing as opposed to 2D massing.		X	X	
The use of site-specific data about sustainable principles and approaches.		X	X	
The use of a site plan to discuss the project in its context.		X	X	
The use of architectural drawings (plans, section, elevations, or illustrative material) to scale (note diagram) showcases response to materials and construction techniques proposed for the project.		X	X	
Capable %	0% 0/5*100		100% 5/5*100	

	Cohort 1: Conventional Method		Cohort 2: BIM Method	
Responsiveness	1	No Capability	4	Complete Capability

The lack of engaging critically with the project's needs and requirements was the first concern established by the CM cohort. Students struggled to produce work for the first critique session by not specifying an accommodation schedule, which resulted in students not attending the critique session. This was also evident in later critique sessions where students were still uncertain of what their project was about due to not establishing the project's requirements. On the other hand, students who used the BIM method established an accommodation schedule with physical restrictions and a qualitative position on what is required for the different spaces as quantitative and qualitative information is required beforehand. One-dimensional isolated communication was observed from the CM cohort due to the lack of varying drawing types produced compared to full three-dimensional discussions around the critique table observed by the BIM cohort, which had various drawing types.

For the CM to produce drawings, it was confined or limited to the particular student's ability. Furthermore, the CM used generic sustainable principles obtained as a general rule of thumb in another module. In contrast, the BIM cohort used site information that was factually based on geolocation abilities. In summary, the CM cohort indicated 'no capability', whereas the BIM cohort has the capability to affect design information to a full extent.

Within the **Relationship** attribute, five areas were outlined. Table 4 summarises the criteria for evaluation.

Table 5: Results pertaining to the Relationship attribute

Capability matrix for relationship	**CM**		**BIM**	
Requirement criteria to meet the attribute	Yes	No	Yes	No
Architectural drawings must correlate between different drawing types (plans to sections to elevations to 3Ds).		X	X	
Architectural drawings should explain/communicate the understanding of both the relationship between interior spaces and exterior spaces.	X		X	
Architectural drawings must be clear, precise and legible.	X		X	
The relationship between construction technique and spatial planning must be indicated.		X	X	
The use of different platforms to complete the design process without redoing work in any platform.		X	X	
Capable %	40% 2/5*100		100% 5/5*100	
	Cohort 1: Conventional Method		Cohort 2: BIM Method	
Relationship	2	Minimum Capability	4	Complete Capability

The main issue experienced is the drawing techniques used by the CM cohort were not legible compared to the universal BIM standards that promote legibility as indicated in Figure 3. The BIM cohort produced information-rich drawings that facilitated discussion about internal and external relationships. The CM cohort had little information on their drawings that were cross-referenced and made conversations impossible. Due to the manual drafting method used by the CM cohort, drawings were error-prone and did not correlate to each other. The digital modelling that the BIM cohort followed allowed for constant cross-reference of drawings that eliminated any upfront errors.

The parametric manner of working with BIM allowed for the ease of modification. BIM models have rich information about the object, whereas the CM represents objects with no relevant, intelligent information. With the lack of structural or material information available from the CM, discussions dealing with the relationship between structure and spatial planning did not occur. BIM allowed students to work between different platforms without redoing, reworking, or redrawing, which assisted in discussion to develop around the relationship between space and structure. The ability to link to multiple platforms was not evident in the CM. As a result, a minimum capability rating was achieved using the CM compared to a BIM cohort that received a complete capability rating.

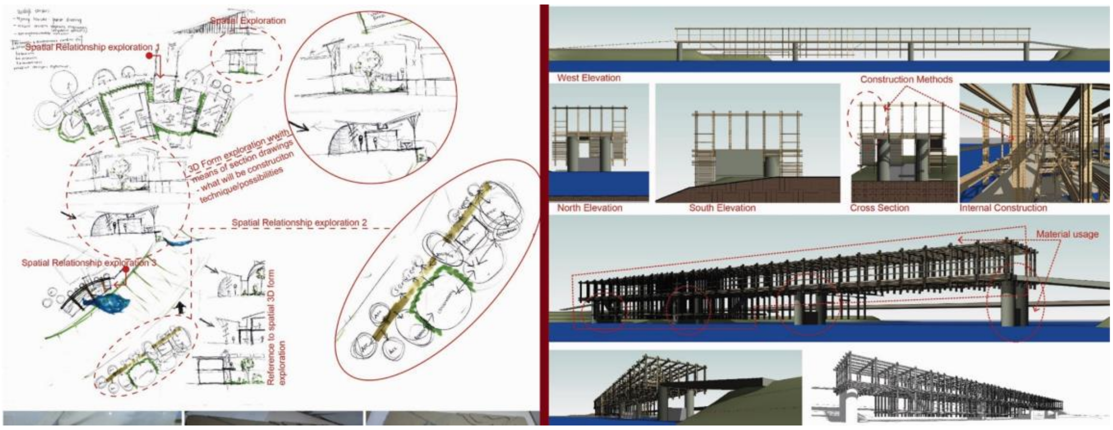

Figure 15: The BIM (right) promotes universal drawing standards compared to CM (left)

Modification can be regarded as the extent to which the design can be modified and explored. Table 5 outlines the criteria for modification.

Table 6: Results pertaining to the Modification attribute

<table>
<tr><th colspan="2">Capability matrix for modification</th><th colspan="2">CM</th><th colspan="3">BIM</th></tr>
<tr><td colspan="2">Requirement criteria to meet the attribute</td><td>Yes</td><td>No</td><td colspan="2">Yes</td><td>No</td></tr>
<tr><td colspan="2">Any component of the work presented can be modified with ease without redrawing, modelling, or physically rebuilding a component</td><td></td><td>X</td><td colspan="2">X</td><td></td></tr>
<tr><td colspan="2">Ability to modify components in both 3D and 2D simultaneously</td><td></td><td>X</td><td colspan="2">X</td><td></td></tr>
<tr><td colspan="2">Ability to provide sequential process work</td><td>X</td><td></td><td colspan="2">X</td><td></td></tr>
<tr><td colspan="2">Low time-consuming process to modify objects</td><td></td><td>X</td><td colspan="2">X</td><td></td></tr>
<tr><td colspan="2">Capable %</td><td colspan="2">25%
1/4*100</td><td colspan="3">100%
4/4*100</td></tr>
<tr><td></td><td colspan="3">Cohort 1: Conventional method</td><td colspan="3">Cohort 2: BIM method</td></tr>
<tr><td>Modification</td><td>2</td><td colspan="2">Minimum capability</td><td>4</td><td colspan="2">Complete capability</td></tr>
</table>

BIM models were easily modified to meet critique sessions, whereas the CM did not promptly modify the requested changes. By using pen-and-paper or basic computer drafting, modification of any proposal is a manual process in nature. Any new submission required the students to redraw a great volume of the existing content to make the selective changes in one part of the design. Not only is it time-consuming, but it also creates room for error in the redrawing process that can easily not be picked up by the student. BIM produced a range of different drawing types and improved the quality and legibility of the project by reducing the risk of drawing errors.

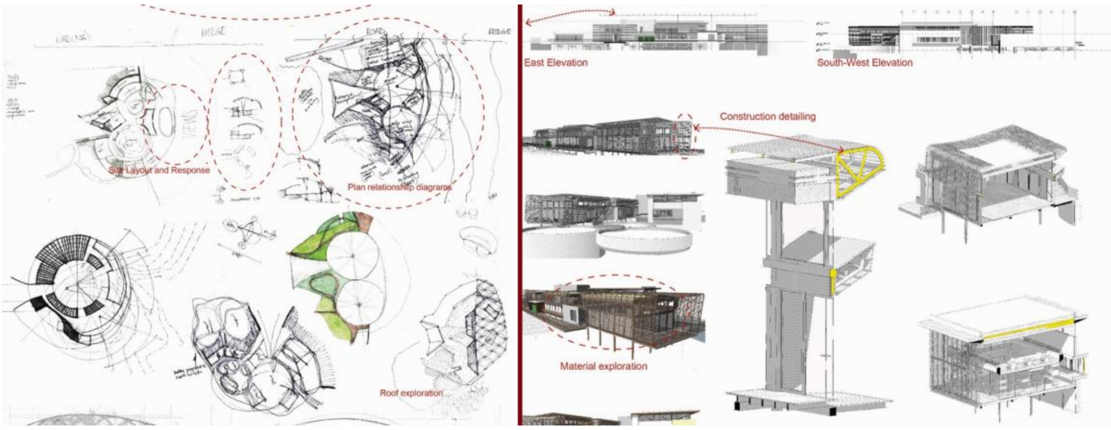

Figure 16: Using BIM allowed students to easily modify their proposal and engage in critique compared to the manual process (left)

While working holistically (BIM), it assisted the students in identifying problems as early as the conceptual stage. Now that the problems are recognised and established upfront, students can develop their design in more detail. Thereby the level of **accuracy** improved, as outlined in Table 6.

Table 7: Results pertaining to the attribute Accuracy

Capability matrix for accuracy	**CM**		**BIM**	
Requirement criteria to meet the attribute	Yes	No	Yes	No
There is no need to redraw/trace work to reproduce or modify work		X	X	
Components are seen as identifiable objects rather than as individual line components		X	X	
Representation of building elements to scale, dimension, and thickness		X	X	
The project is situated on a site plan		X	X	
Capable %	0% 0/4*100		100% 4/4*100	
	Cohort 1: Conventional method		Cohort 2: BIM method	
Accuracy	1	No capability	4	Complete capability

Using parameters within the BIM cohort, accuracy was achieved. Parameters stay constant and evident throughout the whole project duration. In the CM, the student's limitations and skills prohibited the student from producing accurate drawings. Using the CM, objects are seen as simple drawing components, such as four lines labelled a wall with no fixed relationship. Due to the limited time, CM students limited their drawings to plans only, not showing sections, elevations, and site plans. The BIM method allowed students to create parametric models, which assisted in speeding up the process, eliminating redrawing or modelling objects. Therefore, BIM scored 4 and CM 1.

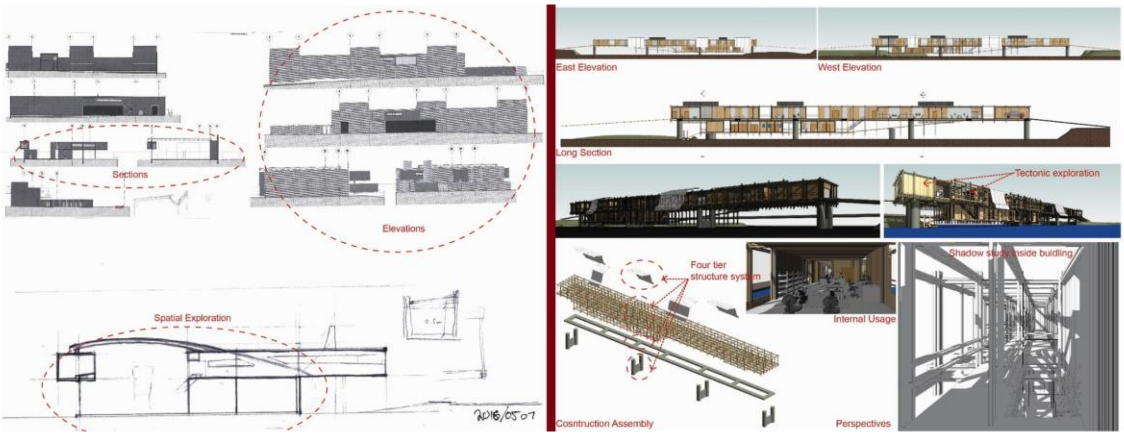

Figure 17: CM (left) restricted accuracy based on the students' ability

Under **Intelligence**, which refers to the ability of an object to identify real-world building components, CM holds no capability to indicate intelligence, as indicated in Table 7.

Table 8: Results pertaining to attribute Intelligence

Capability matrix for intelligence	**CM**		**BIM**	
Requirement criteria to meet the attribute	Yes	No	Yes	No
Can the architecture component react in an intelligent manner to a real building component?		X	X	
The project is located to a specific geographical relation and site-specific information is obtained		X	X	
Capable %	0% 0/2*100		100% 2/2*100	

	Cohort 1: Conventional method		Cohort 2: BIM method	
Intelligence	1	No capability	4	Complete capability

Firstly, sustainable factors were not factual and accurate in work presented by the CM cohort. For example, generic information was used for a region, or sometimes students did not manage to source information for that region. As this is a crucial initial design step, students started conceptual design using the wrong information, which resulted in students returning the drawing board later in the design project. The BIM cohort used intelligent information from the global mapping service embedded in the software with accurate weather data, updated in real-time. Secondly, when the students used mass models to investigate possible building orientation and building shape, the CM cohort used the manual calculation compared to using the global mapping solar information, updated as the model updated. The BIM cohort used the solar information during each step of the process, monitoring each move to ensure that their building reaches the most efficient sustainable rating, resulting in an accurate passive design approach. Therefore, BIM had the complete capability (4) and CM no capability (1).

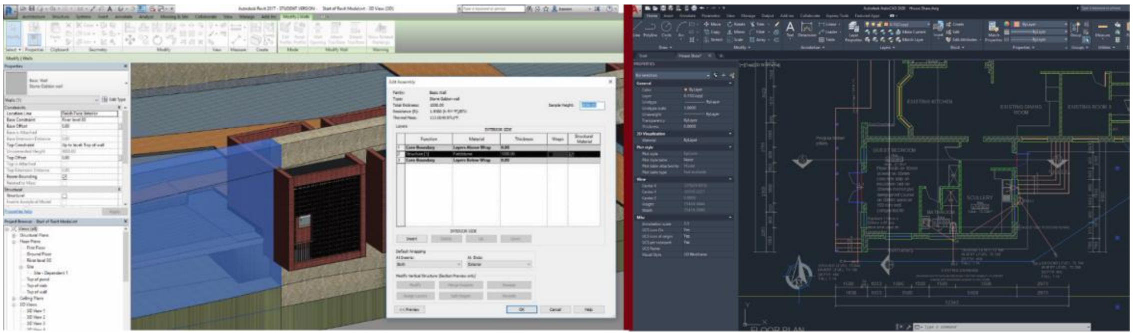

Figure 18: BIM allows for objects to be seen as real-world objects containing information (left) compared to line-based drawings

To communicate to a range of clients, architects rely highly on **Representation** techniques, and it requires specific criteria as outlined in Table 8.

Table 9: Results pertaining to the attribute Representation

Capability matrix for representation	**CM**		**BIM**	
Requirement criteria to meet the attribute	Yes	No	Yes	No
Representation is retrieved holistically, not drawn as individual elements		X	X	
Includes representation material from 2D plans, section and elevation and 3D illustrations	X		X	
Expressing materiality in illustrative material.		X	X	
Capable %	33.3% 1/3*100		100% 3/3*100	

	Cohort 1: Conventional method		Cohort 2: BIM method	
Representation	2	Minimum capacity	4	Complete capability

The CM cohort used various representation techniques, including sketches, drawings, physical models, and basic line drawings, as highlighted earlier. In most of the work, no 3D material was provided and engaging with the proposal is problematic. It led to miscommunication and frustration by both the lecturer and the student. Therefore, CM scored a minimum capability (2). BIM assisted students in producing a variety of different drawing types, including illustrative 3D material. Communication was easy to follow with no misinterpretation. The BIM models also allowed for linking to other printing platforms, such as 3D printing, which saved students time. Therefore, BIM achieved a complete capability factor rating of 4.

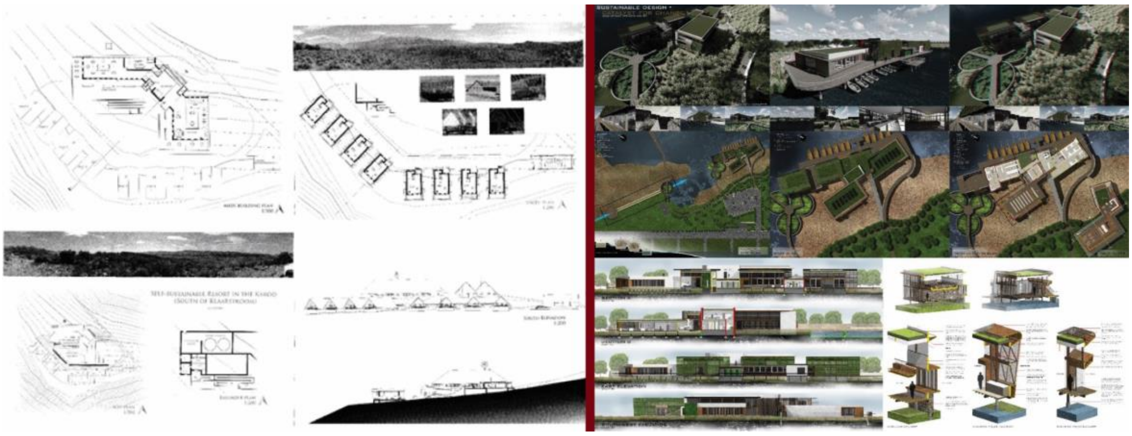

Figure 19: BIM allowed students to represent their design proposal using different illustrative material as well as the opportunity to link to other platforms, such as 3D printing

From this research, the following four themes are prominent:

1. Competencies: Signs include the quality of the drawing technique, accuracy and the availability of a drawing range;
2. Relationship: Signs include project information that is not prior defined by the student, the lack of understanding of spatial relationships between structure and internal space;
3. Time and cost: By implementing the BIM method, the research has shown that students spend an estimated 94 hours (47%) less time on a project than using the CM, and
4. Non-participation: Due to the complex nature of the design approach and not fully exploring "What if?" scenarios, students tend to stay away from critique sessions.

Conclusion

Students seem to struggle to submit their studio-based design projects on time using the CM. Compared to the CM, the BIM method improved communication between the student and the lecturer based on the capability to improve the information by meeting the design quality attributes of responsiveness, relationship, modification, accuracy, intelligence, and representation. The CM limited the ability of students to exchange information during critique sessions with the relevant staff members; it also hindered the production of information sets in the form of drawings and, therefore, did not improve communication between the student and the lecturer. Four early signs to detect miscommunication were identified as a guideline, and these include competencies, relationship, time and cost, and non-participation.

It is thus evident that the CM did not improve communication, whereas BIM improved communication between the student and the lecturer. A 47% time-saving by students using the BIM method shows a greater level of efficiency, which directly impacted their submission rate, as they submitted complete projects on time.

Implementing IT such as the BIM method in the design studio, efficiency, communication of well-informed design knowledge and improved submission rates instead of the traditional CM are promoted. Innovation and research into teaching methods could contribute to effective teaching and communication among millennials in the architecture profession.

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